AATD TR10-D-93

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US Coast Guard ASIST Probe Evaluation on a H-65 Dolphin

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May 2010

DISTRIBUTION STATEMENT

Distribution Statement A: Approved for Public Release, Distribution is unlimited.

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)* 27 May 2010	**2. REPORT TYPE** Test Report	**3. DATES COVERED** *(From - To)* 12 April – 10 May

4. TITLE AND SUBTITLE US Coast Guard ASIST Probe evaluation on a H-65 Dolphin	**5a. CONTRACT NUMBER**
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) John Crocco	**5d. PROJECT NUMBER**
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Aviation Applied Technology Directorate Building 401, Lee Blvd RDMR-AAF Fort Eustis, VA 23604-5577	**8. PERFORMING ORGANIZATION REPORT** AATD-TR10-D-93
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) United States Coast Guard Aviation Logistics Center SRR Aircraft Division Bldg 75 Elizabeth City, NC 27909	**10. SPONSOR/MONITOR'S ACRONYM(S)** ALC
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Distribution Statement A: Approved for Public Release, Distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The United States Coast Guard (USCG) operates a fleet of H-65 Dolphin aircraft. Support for the H-65 fleet is provided by the USCG Aviation Logistics Center in Elizabeth City, NC. The Aircraft Ship Integrated Secure and Traverse (ASIST) system has been installed on the USCG National Security Cutter. The ASIST system is used to secure aircraft to the NSC as well as move the aircraft from the landing pad. The ASIST system includes two components that may affect ground resonance characteristics of the aircraft: A retractable probe that extends from the bottom of the aircraft, and a Rapid Securing Device ground handling system that captures the probe and moves the aircraft off of the helicopter pad. The ALC has been tasked with outfitting one H-65 aircraft with a prototype ASIST system for an operational evaluation of the system on the NSC. Prior to testing on an NSC, an evaluation of the effects of the ASIST system on ground resonance is desired. This report documents the results of risk mitigation testing to evaluate potential ground resonance effects and structural loading of the ASIST probe.

15. SUBJECT TERMS
Ground Resonance, H-65, Dolphin, ASIST

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT UNCLASSIFIED	**b. ABSTRACT** UNCLASSIFIED	**c. THIS PAGE** UNCLASSIFIED	SAR	36	John Crocco
					19b. TELEPHONE NUMBER *(include area code)* 757-878-3008

Changes and Updates

Revisions:

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Test Objectives

The primary objective of this test was to document any ground resonance characteristics of the H-65 Dolphin Aircraft with the Aircraft Ship Integrated Secure and Traverse (ASIST) retractable probe installed, and document any effects that attachment to the ground handling system may have on the ground resonance characteristics. A secondary objective was to generate data to allow for correlation of the static loading of the ASIST probe with an ALC contractor provided finite element model.

The test program was executed at the Aviation Applied Technology Directorate AATD tethered hover pad at Felker Airfield, Ft. Eustis and at the United States Coast Guard (USCG) Elizabeth City airfield. This report covers ground resonance testing conducted 13 April 2010 at Ft. Eustis, VA and static load testing conducted 10 May at Elizabeth City NC by AATD personnel.

References

a) 365N Essisis De Resonance Sol Et De Vibrations Appareil Suspendu, Volume II, Appendix A, 29 August 1983.
b) AATD TEST PLAN ASIST H-65 Ground Resonance Evaluation, 8 April 2010
c) ASIST Ground Resonance Test Results, Model: Eurocopter HH-65 Dauphin, Global Helicopter Technology Inc, Report #08-089-6711C-1, 12 May 2010

Background

The Coast Guard operates a fleet of H-65 Dolphin aircraft with logistics support provided by the Coast Guard Aviation Logistics Center (ALC) in Elizabeth City, NC. The fleet of H-65 aircraft is currently configured to use a TALON system which secures the aircraft to the landing pad but does not traverse the aircraft once on deck.

INDAL has developed the Aircraft Ship Integrated Secure and Traverse (ASIST) system as an alternative to the current TALON system for the H-65 aircraft. The ASIST system allows both the securing of the aircraft to the ship as well as moving the aircraft from the landing pad.

As part of the evaluation of the ASIST system, it has been installed on the U.S. Coast Guard National Security Cutter (NSC) with ALC being tasked with outfitting one H-65 aircraft with a prototype ASIST system for an operational evaluation of the system. Prior to the operational evaluation on the NSC, an evaluation of the effects of the ASIST system on the ground resonance of the H-65 is desired. Two components of the ASIST system have been identified as having the potential to affect the resonance characteristics of the aircraft on the ground: A retractable probe that extends from the bottom of the aircraft, and a Rapid Securing Device (RSD) ground handling system that captures the probe and moves the aircraft off of the helicopter pad.

The H-65 was originally certified under FAR part 29. The installation of the ASIST system was designed to be suitable for an application for a FAA supplemental type certificate, with exceptions approved by ALC H-65 Product Line.

Prior Vibration Testing

In 1983 a series of vibration tests of the 365N was performed to determine the natural frequencies and dampening of the fuselage modes that affect ground resonance. The results of the tests were reported (Reference a). The following conclusions are made from a review of the report:

- Only the roll mode of the airframe on the landing gear is of concern for a potential ground resonance problem. This mode is at 1.5 Hertz (90 rpm) with the rotor inplane mode crossing at 4.33 Hertz (260 RPM). Although a second Yaw-Roll mode was identified, its frequency was above the max autorotation RPM, and therefore cannot coincide with the rotor mode while the aircraft is on the ground.
- There is a high level of damping in the roll mode with a large margin from any instability. This will allow a significant change in the roll mode frequency and damping before the stability margin is reduced to a potentially dangerous level.
- There were very small changes in the frequency (less than 0.1 Hertz) and dampening throughout the gross weight ranges tested (2200 Kg to 3800 Kg).
- There was no attempt to test for deflated tires or improperly serviced oleos.
- Nose gear orientation had only slight effect on the roll mode, and therefore, most likely would not bring into question aircraft stability.

Test Personnel

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Steve Paris	Safety	757-878-2976
Dave Balthazar	Pilot	
Ronald Bowman	Photography	
Stan Aiton	Instrumentation	
Michael Bouchard	United States Coast Guard, ALC	252 335-6843

Test Overview

Three test conditions, two ground resonance and one static, were performed as part of this effort. The first Ground Resonance Test (GRT) case was a baseline evaluation of the aircraft's response to ground resonance excitation with the ASIST probe installed but not fastened to the ground capture system (RSD) simulator. This test, when compared to the prior ground resonance test, will identify any impact resulting from the installation of the ASIST hardware on the H-65.

The second test condition was an evaluation of the aircraft's response to ground resonance excitation with the ASIST probe installed and fastened to the RSD simulator. In both cases, the aircraft configuration was not modified. Video photography was used to capture the test events. Instrumentation and recording of accelerations and displacements on the aircraft during the dynamic tests was conducted by ALC contractors.

For both of the GRT's, a static natural frequency assessment was made. Then the rotor RPM was adjusted from 210 – 360 revolutions per minute (RPM) in 5 hz increments to determine ground resonance characteristics. At each RPM tested, cyclic stir excitations were input into the system at a frequency that was the difference between the rotor RPM and the static natural frequency:

$$\text{Input Frequency} = \text{Rotor Frequency (Hz)} - N_f$$

Equation 1

In some instances, due to the response from the cyclic stir excitation, further testing was conducted that included: increasing amplitude of the cyclic stir, changing the direction of the cyclic stir, or inputting collective pulses, all at the same input frequency. For the second GRT only, standard start up and shut down procedures were also evaluated for the potential to change the ground resonance response of the H-65.

A static load test was also conducted to provide data in order to allow for the evaluation of the ALC's analytical model of the aircraft structure with the probe under static load. For this test, the ASIST probe was loaded in the fore/aft and port starboard directions independently in 500 lb increments up to 2000 lbs.

The aircraft used for both the GRT and the static testing was Coast Guard Aircraft #6583, an MH-65C with the ASIST Probe installed (Figure 1).

Figure 1 – Aircraft with Probe Installed

Ground Resonance Tests

Setup

The aircraft was tested at the AATD tethered hover pad (Figure 2), facing a northwest direction (Figure 3). The Auxiliary Ground Power Unit (AGPU) was used to provide ground power because the aircraft onboard electrical generators tend to shut down at low rotor RPM. As a safety precaution, tie down straps (yellow straps visible in Figure 2) were attached from the aircraft to the ground, but remained slack so that they do not interfere with the resonance characteristics of the aircraft.

Figure 2 – Aircraft At Tethered Hover Pad

Figure 3—Test Setup and Camera Locations

For the first GRT test sequence, the probe was installed on the aircraft, but was retracted into the airframe. For the tests with the ASIST probe attached to the RSD simulator, the probe was extended and attached to an AATD fabricated test fixture that simulated the geometry, and stiffness of the RSD capture device (Figure 4). The RSD capture claw that surrounds the probe was designed to approximate the lateral stiffness of the RSD simulator and fabricated from 17-4 stainless steel, 1025 heat treated as is the actual RSD.

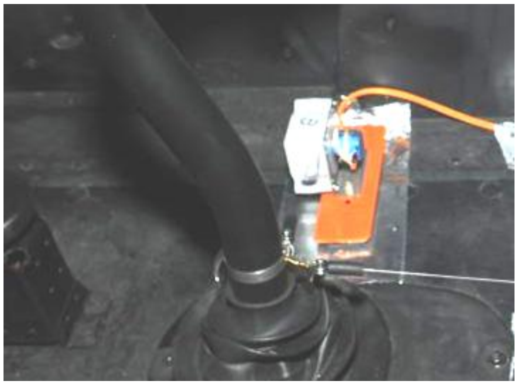
The bottom of the probe did not contact the top of the test fixture (i.e. ground) when extended. An adjustable Turbomeca FADEC (Full Authority Digital Engine Controller) was used to adjust the rotor RPM to the desired value. Due to concerns of exciting resonance inside the engine, the FADEC controller is designed to not allow continuous operation between 300 and 320 RPM so this rotor RPM range was not tested.

Figure 4—RSD Simulator Test Fixture

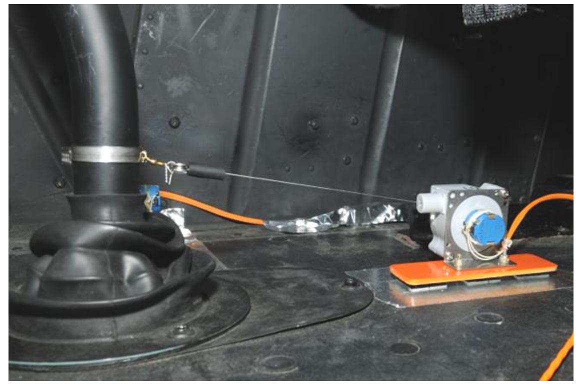
Video was used to capture the test events. Real time video cameras were placed in strategic locations to capture motions of the aircraft due to ground resonance (Figure 6), as well as interactions at the probe / RSD simulator interface (Figure 7). All ground resonance testing was conducted on the hover pad (Table 1). For the static roll tests, the aircraft was rocked by personnel to obtain the airframe roll natural frequency. Once the aircraft was rocking on the two main landing gears, the number of cycles that occurred over a ten second interval were counted. This can be used to calculate the natural frequency of the airframe (without rotors spinning). For the dynamic tests, rotor RPM, excitation type and frequency, and engine torque were recorded by AATD test personnel prior to execution of each test sequence.

Acceleration and displacements on the aircraft were recorded by ALC personnel at various points on the aircraft (Figure 5), to include: nose and main landing gear accelerations, and displacements, cyclic control and collective control displacements, and acceleration inside the cabin. Data was collected at a 100 Hz sample rate with a 5 Hz low-pass filter .

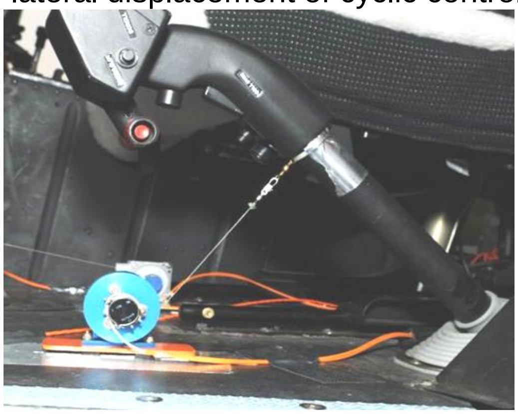
A USCG (ALC) provided test pilot operated the aircraft and a UCSG flight mechanic was the co-pilot. A Turbomecha technician was in the cabin and controlled rotor RPM via the FADEC controller. All other personnel were located southwest of the aircraft to capture data and witness the event.



a. – lateral displacement of cyclic control



b.- fore/aft displacement of cyclic control



c. - displacement of collective

d. - acceleration in cabin

e.- displacement and acceleration of gears

Figure 5 – Instrumentation Locations On Aircraft

The excitation type and frequency were conducted as follows. The initial excitation was a circular ‘stirring’ of the cyclic stick in a counter-clockwise direction. The pilot would set a strobe light to pulse at the desired frequency and then stir the stick at one rotation with each pulse of the strobe. The magnitude of the stir (i.e. the diameter of the stir circle) was such that one rotation would not require excessive force. In some cases, after reviewing the data obtained from the initial excitation for a given RPM, variations were executed at the same RPM. In some cases the magnitude of the stir would be increased to the most

that can be achieved by the pilot (MAX STIR). In one case the cyclic rotation was reversed from a counter-clockwise to a clockwise direction. In two cases, a pure lateral (left/right) excitation of the cyclic was applied. In one case, instead of a cyclic excitation, a collective was pulsed at the input frequency to excite the aircraft.

Figure 6 – Camera Locations, Overall Aircraft

Figure 7 – Camera Locations – Probe Close Up

Table 1—Ground resonance test matrix

Test Case #	Description	Data Req. / Description
S1	Static roll test RSD– natural freq. determination, probe attached to RSD	Roll natural frequency
S2	Static roll test baseline – natural freq. determination, probe not attached	Roll natural frequency
--	“Baseline” GRT Setup	Setup aircraft and test equipment
1	Standard System startup, Probe not attached to RSD	Roll displacement, acceleration, Video, rotor RPM
2	Standard System shutdown, Probe not attached to RSD	Roll attitude, acceleration, Video, rotor RPM
3	Rotor freq. adjusted to 210 RPM	Roll attitude, acceleration, Video, rotor RPM
4	Rotor freq. adjusted to 215 RPM	Roll attitude, acceleration, Video, rotor RPM
5	Rotor freq. adjusted to 220 RPM	Roll attitude, acceleration, Video, rotor RPM
6	Rotor freq. adjusted to 2225 RPM	Roll attitude, acceleration, Video, rotor RPM
7	Rotor freq. adjusted to 230 RPM	Roll attitude, acceleration, Video, rotor RPM
8	Rotor freq. adjusted to 235 RPM	Roll attitude, acceleration, Video, rotor RPM
9	Rotor freq. adjusted to 240 RPM	Roll attitude, acceleration, Video, rotor RPM
10	Rotor freq. adjusted to 245 RPM	Roll attitude, acceleration, Video, rotor RPM
11	Rotor freq. adjusted to 250 RPM	Roll attitude, acceleration, Video, rotor RPM
12	Rotor freq. adjusted to 255 RPM	Roll attitude, acceleration, Video, rotor RPM
13	Rotor freq. adjusted to 260 RPM	Roll attitude, acceleration, Video, rotor RPM
14	Rotor freq. adjusted to 265 RPM	Roll attitude, acceleration, Video, rotor RPM
15	Rotor freq. adjusted to 270 RPM	Roll attitude, acceleration, Video, rotor RPM
16	Rotor freq. adjusted to 275 RPM	Roll attitude, acceleration, Video, rotor RPM
17	Rotor freq. adjusted to 280 RPM	Roll attitude, acceleration, Video, rotor RPM
18	Rotor freq. adjusted to 285 RPM	Roll attitude, acceleration, Video, rotor RPM
19	Rotor freq. adjusted to 290 RPM	Roll attitude, acceleration, Video, rotor RPM

20	Rotor freq. adjusted to 295 RPM	Roll attitude, acceleration, Video, rotor RPM
21	Rotor freq. adjusted to 300 RPM	Roll attitude, acceleration, Video, rotor RPM
22	Rotor freq. adjusted to 320 RPM	Roll attitude, acceleration, Video, rotor RPM
23	Rotor freq. adjusted to 325 RPM	Roll attitude, acceleration, Video, rotor RPM
24	Rotor freq. adjusted to 330 RPM	Roll attitude, acceleration, Video, rotor RPM
25	Rotor freq. adjusted to 335 RPM	Roll attitude, acceleration, Video, rotor RPM
26	Rotor freq. adjusted to 340 RPM	Roll attitude, acceleration, Video, rotor RPM
27	Rotor freq. adjusted to 345 RPM	Roll attitude, acceleration, Video, rotor RPM
28	Rotor freq. adjusted to 350 RPM	Roll attitude, acceleration, Video, rotor RPM
29	Rotor freq. adjusted to 355 RPM	Roll attitude, acceleration, Video, rotor RPM
30	Rotor freq. adjusted to 360 RPM	Roll attitude, acceleration, Video, rotor RPM
--	“Probe attached” GRT setup	Setup aircraft, attach Probe to RSD simulator, and setup test equipment
31	Rotor freq. adjusted to 210 RPM	Roll attitude, acceleration, Video, rotor RPM
32	Rotor freq. adjusted to 215 RPM	Roll attitude, acceleration, Video, rotor RPM
33	Rotor freq. adjusted to 220 RPM	Roll attitude, acceleration, Video, rotor RPM
34	Rotor freq. adjusted to 2225 RPM	Roll attitude, acceleration, Video, rotor RPM
35	Rotor freq. adjusted to 230 RPM	Roll attitude, acceleration, Video, rotor RPM
36	Rotor freq. adjusted to 235 RPM	Roll attitude, acceleration, Video, rotor RPM
37	Rotor freq. adjusted to 240 RPM	Roll attitude, acceleration, Video, rotor RPM
38	Rotor freq. adjusted to 245 RPM	Roll attitude, acceleration, Video, rotor RPM
39	Rotor freq. adjusted to 250 RPM	Roll attitude, acceleration, Video, rotor RPM
40	Rotor freq. adjusted to 255 RPM	Roll attitude, acceleration, Video, rotor RPM
41	Rotor freq. adjusted to 260 RPM	Roll attitude, acceleration, Video, rotor RPM
42	Rotor freq. adjusted to 265 RPM	Roll attitude, acceleration, Video, rotor RPM

43	Rotor freq. adjusted to 270 RPM	Roll attitude, acceleration, Video, rotor RPM
44	Rotor freq. adjusted to 275 RPM	Roll attitude, acceleration, Video, rotor RPM
45	Rotor freq. adjusted to 280 RPM	Roll attitude, acceleration, Video, rotor RPM
46	Rotor freq. adjusted to 285 RPM	Roll attitude, acceleration, Video, rotor RPM
47	Rotor freq. adjusted to 290 RPM	Roll attitude, acceleration, Video, rotor RPM
48	Rotor freq. adjusted to 295 RPM	Roll attitude, acceleration, Video, rotor RPM
49	Rotor freq. adjusted to 300 RPM	Roll attitude, acceleration, Video, rotor RPM
50	Rotor freq. adjusted to 320 RPM	Roll attitude, acceleration, Video, rotor RPM
51	Rotor freq. adjusted to 325 RPM	Roll attitude, acceleration, Video, rotor RPM
52	Rotor freq. adjusted to 330 RPM	Roll attitude, acceleration, Video, rotor RPM
53	Rotor freq. adjusted to 335 RPM	Roll attitude, acceleration, Video, rotor RPM
54	Rotor freq. adjusted to 340 RPM	Roll attitude, acceleration, Video, rotor RPM
55	Rotor freq. adjusted to 345 RPM	Roll attitude, acceleration, Video, rotor RPM
56	Rotor freq. adjusted to 350 RPM	Roll attitude, acceleration, Video, rotor RPM
57	Rotor freq. adjusted to 355 RPM	Roll attitude, acceleration, Video, rotor RPM
58	Rotor freq. adjusted to 360 RPM	Roll attitude, acceleration, Video, rotor RPM
59	Standard System startup, Probe attached to RSD	Roll displacement, acceleration, Video, rotor RPM
60	Standard System shutdown, Probe attached to RSD	Roll attitude, acceleration, Video, rotor RPM
--	Return aircraft to flight status	Detach Probe from RSD simulator and Remove Instrumentation from aircraft

Test Results

For the static roll natural frequency tests, the aircraft was rocked by personnel to obtain the airframe roll natural frequency. Once the aircraft was rocking at a constant frequency on the two main landing gears, rocking was maintained and the number of cycles that occurred over a ten second interval were counted. For the baseline static roll test, 12 cycles were counted. For the static roll test with the probe attached to the RSD, 13 cycles were counted.

For the dynamic tests (Table 2 &Table 3) rotor RPM was recorded, along with the frequency with which the pilot would excite the aircraft via the cyclic or collective. The type of excitation was also recorded. The Engine Torque (%) required at a given rotor RPM was also recorded when the pilot relayed it. Wind speed was monitored and recorded at various times, and is given as a direction and speed. Further explanation of test notes taken is provided as follows. When MAX STIR was initiated, the pilot noted issues with the hydraulic pressure lines actuating the correct response. If tests were repeated, it was noted. Vertical pitching indicates that the aircraft was rocking on its nose gear and one (or both) of its main gear. If the pilot felt contact between the probe and RSD simulator it was noted. Three cameras were used to record the test events and were run continuously. Video tape was changed in all cameras at the same time such that Tape 1 of each camera records events up to test 15, tape 2 records from event 16 to event 19, and tape 3 records events 21 through 44. Test event #20 was intentionally left blank. Data recorded by the ALC is provided in Reference (c). For the baseline tests, maximum deflection of the main landing gear occurred on Test #19 (Figure 8) in which the left side main landing gear oscillated over a range of 0 to -0.1 inches. For the tests with the probe attached to the RSD, maximum deflection of the main landing gear occurred on Test #36 (Figure 9) in which the left side main landing gear oscillated over a range of 0 to -.08 inches. Test #32 had the longest damping time, in which the nose landing gear experienced maximum deflection of 0.112 inches, which dissipated within 1.4 seconds of the pilot removing excitation.

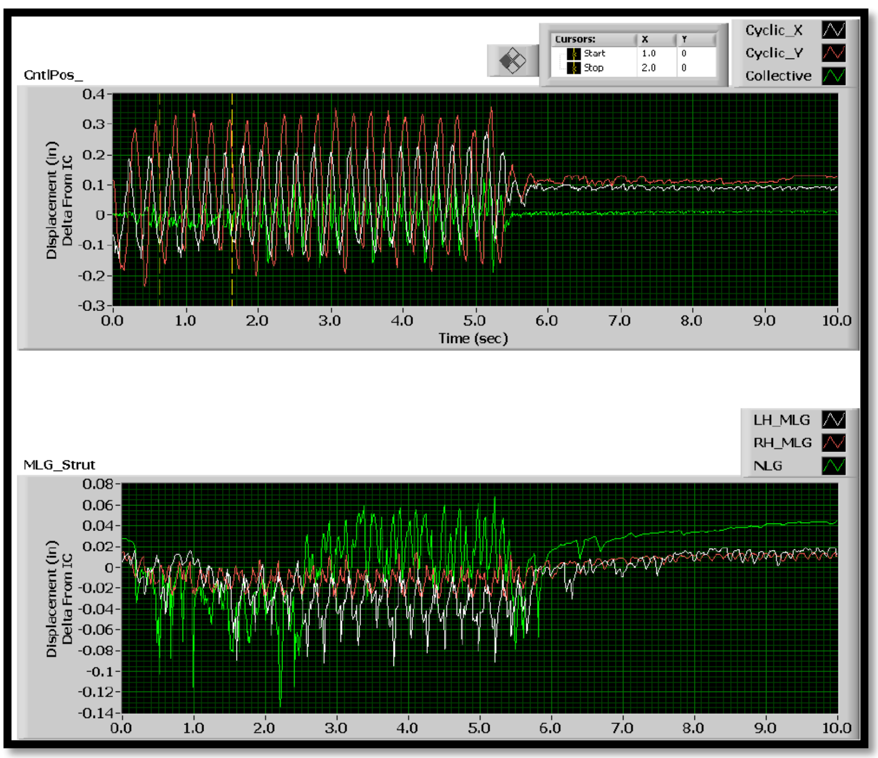


Figure 8 – Test 19 cyclic control input (top) and landing gear response (bottom)

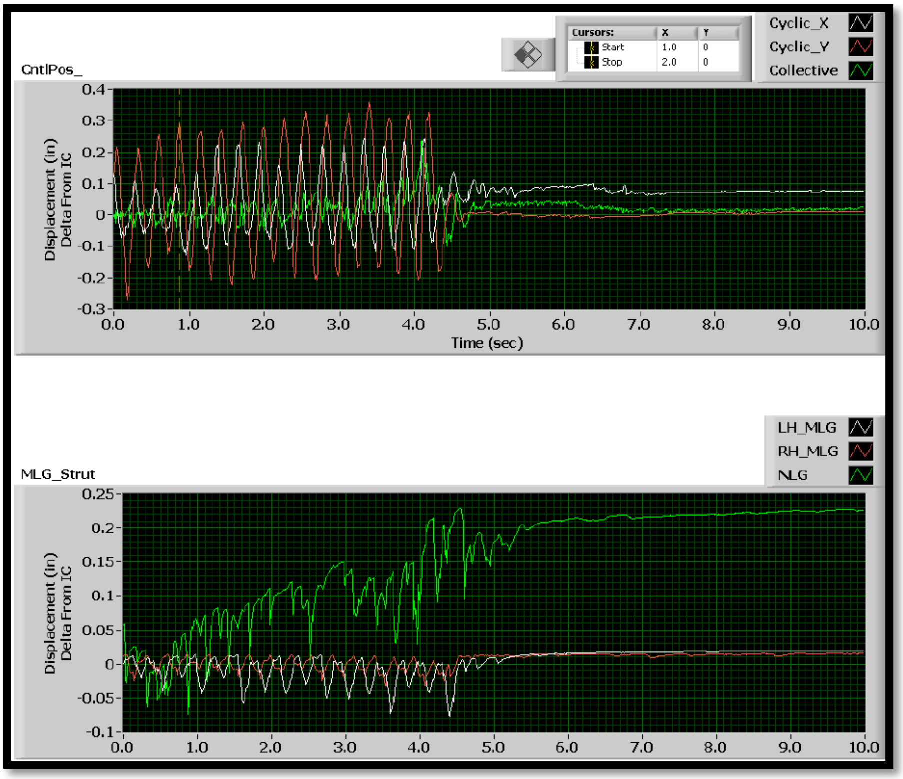


Figure 9 – Test 36 cyclic inputs (top) and landing gear response (bottom)

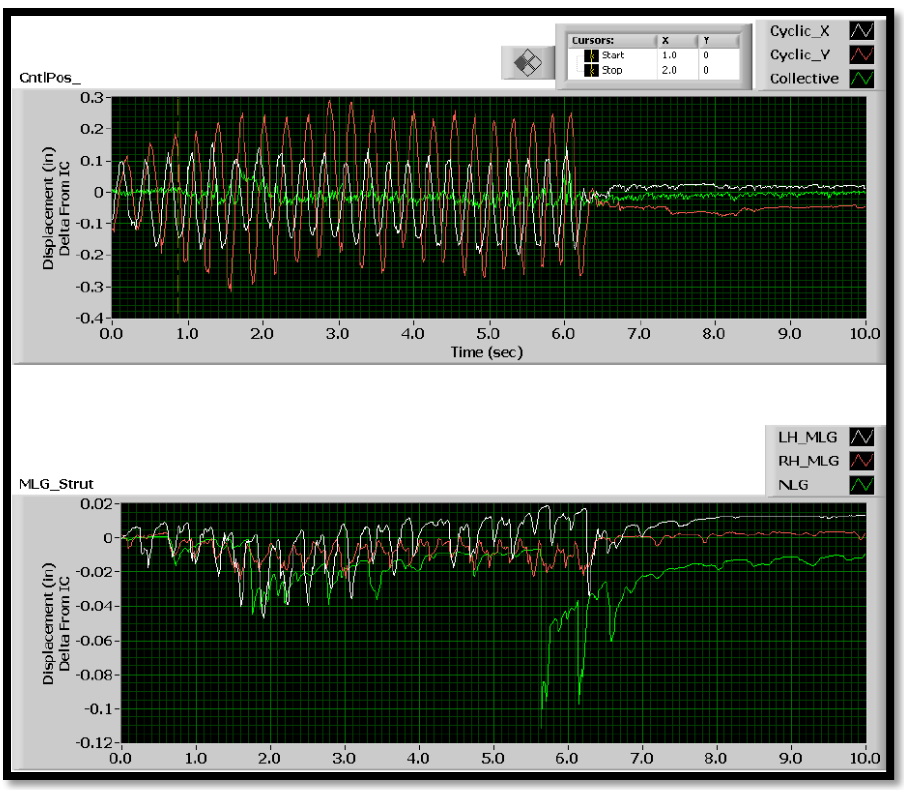


Figure 10 – Test 32 cyclic inputs (top) and landing gear response (bottom)

Table 2 – Baseline test results

Date	13-Apr-10					
AATD Test #	Time (zulu)	RPM	Strir Freq. (Hz)	Stir type	Engine Torque (% tot.)	Notes - Start engine time 1145 zulu (negligable winds)
1	1158	210	3.5	Circular stir		Winds: 120@1kts
2	1201	210	3.5	max stir		max circular stir, pilot noted hydraulic pressure issues while stiring at that freq.
3	1204	220	3.7	max stir		
4	1206	230	3.8	max stir		Winds: 070@2kts
5	1208	230	3.8	max stir		repeat of previous test
6	1211	250	4.2	Circular stir		noticable vertical displacement
7	1221	250	4.2	Reverse direction	12.2	initial stir direction reversed
8	1222	260	4.3	Circular stir	10.2	vertical pitching
9	1227	270	4.5	Circular stir	13	vertical pitching
10	1230	240	4	Circular stir	13	vertical pitching
11	1235	210	3.5	Circular stir		vertical pitching
12	1238	280	4.7	Circular stir		
13	1240	290	4.8	Circular stir		lost AGPU
14	1241	299	5	Circular stir		Lost side view recording, stopped taps
15	1258	320	5.3	Circular stir	17.9	Tape 2 for video
16	1300	330	5.5	Circular stir	18.1	
17	1302	340	5.7	Circular stir	19	Winds: 120@4kts
18	1304	350	5.8	Circular stir	18.9	
19	1305	360	6	Circular stir	20.9	

Table 3 – ASIST probe attached to RSD test results

Date	13-Apr-10					
AATD Test #	Time (zulu)	RPM	Strir Freq. (Hz)	Stir type	Engine Torque (% tot.)	Notes - Start engine time 1145 zulu (negligable winds)
20						Extended Probe and installed Probe Claw
21	1343	210	3.5	Circular stir	3.9	Tape 3 for video, Winds: 120@3kts
22	1345	210	3.5	no stir, collective pulse	3.9	repeat previous but, collective pulse. Pilot noted probe contact with RSD
23	1347	215	3.6	Circular stir	8.8	
24	1349	220	3.7	Circular stir	9	
25	1350	225	3.75	Circular stir	9.4	
26	1352	230	3.8	Circular stir	9.9	Vibration disipates in 2 cycles
27	1355	240	4	Circular stir	10.3	
28	1357	250	4.2	Circular stir	11.4	
29	1359	260	4.3	Circular stir	11.8	
30	1402	270	4.5	Circular stir	12.7	
31	1404	280	4.7	Circular stir		Winds: 120@5kts
32	1406	290	4.8	Circular stir	14.9	pilot noted probe 'tapping' prior to stir excitation
33	1408	295	4.9	Circular stir	14.2	
34	1409	285	4.75	Circular stir	13.4	
35	1411	299	5	Circular stir	14.5	
36	1413	320	5.3	Circular stir	16.4	
37	1416	330	5.5	Circular stir	17	
38	1418	340	5.7	Circular stir	17.4	
39	1420	350	5.8	Circular stir	18.6	
40	1422	360	6	Circular stir	19.9	
41	1425	290	1.3	pure lat. Cyclic		attempt to excite roll mode directly
42	1430	215	1.3	pure lat. Cyclic		attempt to excite roll mode directly
43	1433	ramp up	n/a	n/a		ramp engines from 215-360 rpm
44	1434	shut down	n/a	n/a		recorded shut down from 360 rpm

After testing was complete the RSD simulator and the probe were inspected. At some time during the twenty three tests, the probe impacted the RSD simulator and caused marring on both the probe and RSD simulator. The RSD simulator was fabricated of the same material as the actual RSD: 17-4 Stainless Steel, 1025 heat treated.

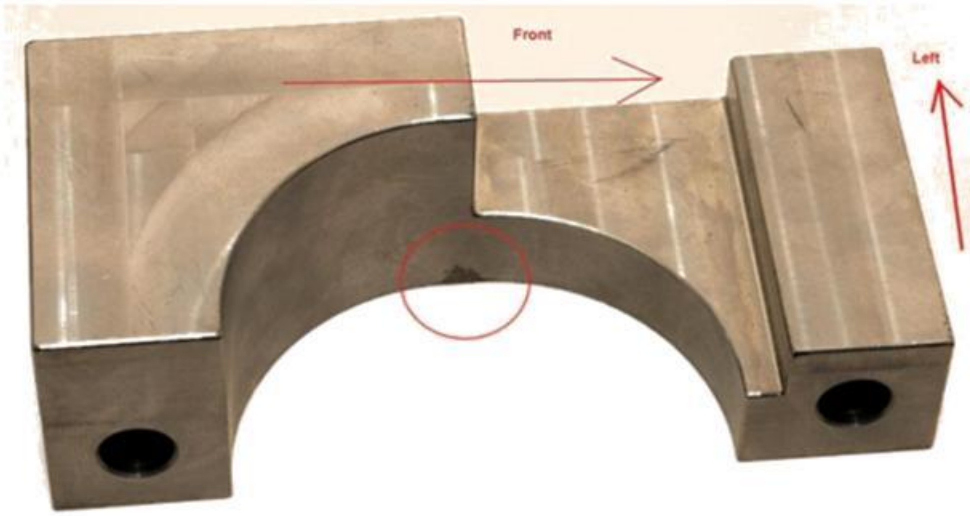


Figure 11 – Damage on RSD simulator fixture post-test

Figure 12 – Damage on RSD simulator fixture post test

Figure 13 – Damage on probe post test.

Analysis of GRT test Results

Static Roll Natural Frequency Test Results

The test results of the static roll test show that there was minimal difference between the roll natural frequency with the aircraft attached to the RSD simulator versus not attached to the RSD simulator. The number of cycles counted can be used to determine the natural frequency (Nf) of the airframe without rotors spinning. (Table 4)

Table 4 – Static Roll Natural Frequency Results

Date	12-Apr-10		
AATD Test #	Static test	Nf	Notes
S1	Probe Attached	1.3	Probe extended and attached to RSD
S2	Static test	1.2	Probe not attached to RSD, and retracted.

The 0.1hz increase most likely due to the probe contacting the RSD simulator and causing an overall increase in the stiffness of the airframe in the lateral direction. An increase in stiffness is directly proportional to an increase in natural frequency:

$$N_f = \sqrt{\frac{k}{m}}$$

Analysis of Baseline test Results

Qualitatively, there was little influence of cyclic stir excitations inducing ground resonance in the aircraft in its baseline configuration. Any induced vibrations dissipated quickly, indicating a damped system. The data indicate that the aircraft never went into ground resonance in the rotor RPM range tested. Vibrations dissipated quickly after excitation was removed.

Analysis of ASIST Probe Attached to RSD Simulator test Results

Qualitatively, there was very little influence of cyclic stir excitations on inducing ground resonance in the aircraft in its baseline configuration. Attempts were also made to excite the aircraft via collective pulsing and pure lateral cyclic excitation. Any induced vibrations dissipated quickly, indicating a damped system. The data indicate that the aircraft never went into ground resonance in the rotor RPM range tested. Comparison to the baseline test indicate that the attachment to the RSD probe had little effect on the vibration characteristics of the aircraft. Vibrations dissipated quickly after excitation was removed. For Test #32, the test case with the longest dissipation time, the rotor in plane mode was synchronized with the roll mode. There was still sufficiently high damping to reduce oscillations with 1.4 seconds, or less than one quarter of the excitation frequency.

Static Load Test

Setup

The static load tests were conducted at the USCG Elizabeth City ALC facility on 10 May by AATD personnel. Single direction strain gauges were installed under the floor, in the fuel bay (Figure 14). The test plan had these gages located on the center beam two inches aft of 51.5 Deg wall support structure corner clips. The gauges on 9 Deg bulkhead were two inches outboard of 51.5 Deg Wall support structure corner clips. These gages had to be adjusted from the test plan locations due to rivets and clips in the area (Table 5). Tri-axial Strain gauges were installed on the belly of the aircraft, on the exterior surface (Figure 17). Strain gauges were oriented positive forward, positive left.

Table 5 – Actual Strain Gage locations in fuel bay area

Gage	Location Description	Location in Test Plan	Final location
T1	Centerline Top	2” aft of 51.5 Deg Wall	3.13" Aft of 51.5Deg Wall
T2	Centerline Bottom	2” aft of 51.5 Deg Wall	3.00" Aft of 51.5Deg Wall
T3	90Deg Bulkhead Top	2” Outboard of 51.5 Deg Wall	2.88" Outboard of 51.5Deg Wall
T4	90Deg Bulkhead Bottom	2” outboard of 51.5 Deg Wall	4.00" Outboard of 51.5Deg Wall

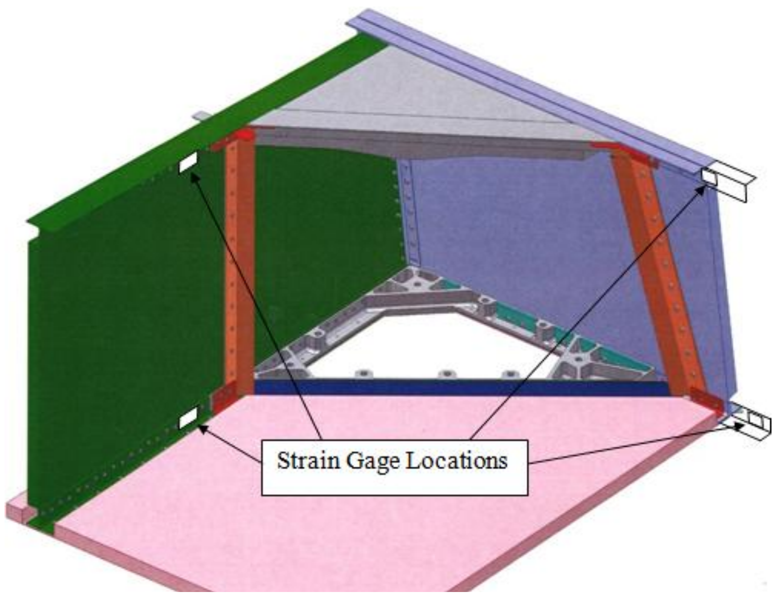


Figure 14 –Internal Strain Gauge General Locations Inside Fuel Bay

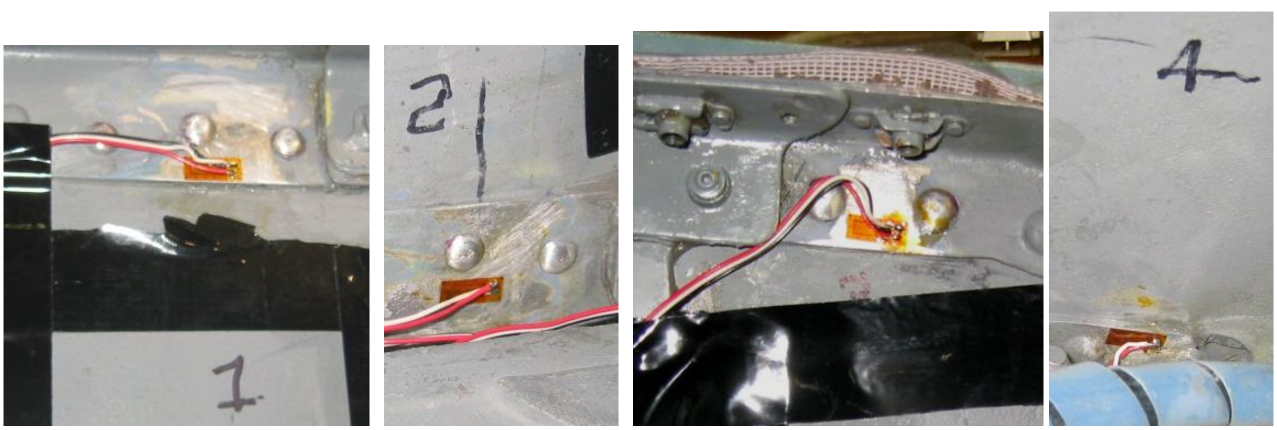


Figure 15 – Actual Strain Gauge Locations Inside Fuel Bay

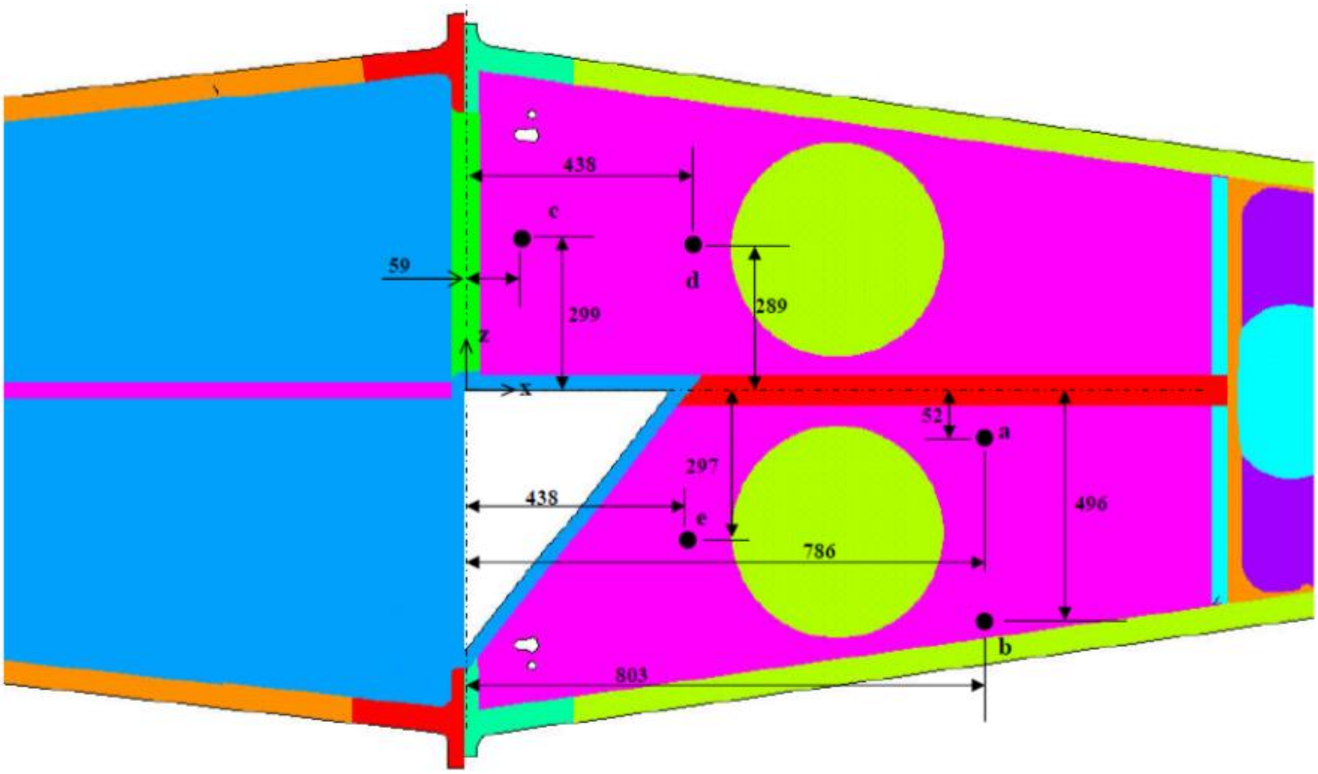


Figure 16 – External Strain Gauge General Locations, on Belly of Aircraft

Figure 17 –Examples of Actual Locations for Gauges at Locations (a) and (e) on Belly of Aircraft

A manual load actuator was attached to the probe via a cargo strap with a load cell in-line (Figure 18). Load was applied up to 2000 lbs in five directions (Table 6) and near parallel with the ground as practical. Five strain surveys were taken between 0-2000 lbs (e.g. 0lbs, 500lbs, 1000lbs, 1500lbs, 2000lbs). Strain gauges were zeroed prior to testing. Resistance calibration was conducted on the data acquisition system pre-test and post test. The aircraft did not move during the conduction of the testing.

Figure 18 – Static Load Test Setup, 270 Deg. (Port) Load Case

Table 6—Static Load Test Matrix

Test Case #	Description	Data Req. / Description
--	Installation of strain gauges	--
1	Port	Load, Strain
2	Starboard	Load, Strain
3	Fore	Load, Strain
4	Aft	Load, Strain

Test Results

Static load test results are provided in Appendix A. Load versus strain was primarily linear. Strain trended to increase in the direction of loading (i.e. lateral strain gauges increased with lateral load) with minimal orthogonal effect. A fifth test was also conducted at 45 degrees center on the starboard side (See Appendix). This test case was conducted in order to provide loading data off axis from the aircraft main axis.

Analysis of ASIST Static Load Test

The test data indicated a linear increase in strain with increasing load, which should be expected. Test data also indicated that strain increased primarily in the loading direction. There was slight nonlinearity between 500-1000 lbs. which may be attributed to the elastomeric attachment of the probe.

Test Summary

There was minimal difference in the static roll mode natural frequency of the baseline aircraft and the aircraft with the ASIST probe attached to the RSD simulator. This indicates that the affect the attached probe has on the ground resonance characteristics should also be minimal. There was also minimal difference between the values measured for this test, and the value of 1.5 Hz from previous vibration assessments (Reference a)).

There was minimal difference in the results of dynamic excitation tests of the baseline aircraft and the aircraft with the ASIST probe attached to the RSD simulator. Post test inspection found scratching and marring of the RSD simulator fixture and the ASIST probe due to vibratory contact between the two parts.

The load/strain values recorded did not indicate yielding of the aircraft structure at the locations measured.

Conclusions

Based on the measurements and observations obtained, it can be concluded that the ASIST probe has minimal affect on the ground resonance characteristics of the H-65 aircraft, in the configurations tested. Marring to the probe and RSD was unexpected. Further investigation may be required to ensure this type of damage does not occur in actual use and or does not affect maintenance of fielded equipment. Further review of the static load analytical model is being conducted by the USCG ALC.

POINT OF CONTACT

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Appendix A: Static Load Test Data Recorded by AATD

Test Execution Description

Strain gauges on the belly were identified by A, B, C, D, E designations (Figure B1) and by 1, 2, 3, 4 inside the fuel bay (Figure B2). The aircraft was statically loaded in five directions (Figure B3) up to 2000 lbs. An additional 45 degree load case was conducted in addition to what was in the test plan (Figure B4) in order to provide loading data off axis from the aircraft main axis. Load and strain were recorded for each test case (Table B1, Figure B5, Figure B6, Figure B7, Figure B8, Figure B9). Comparison of the test data to the finite element model created by Global Helicopter Technology Inc to date is still under review.

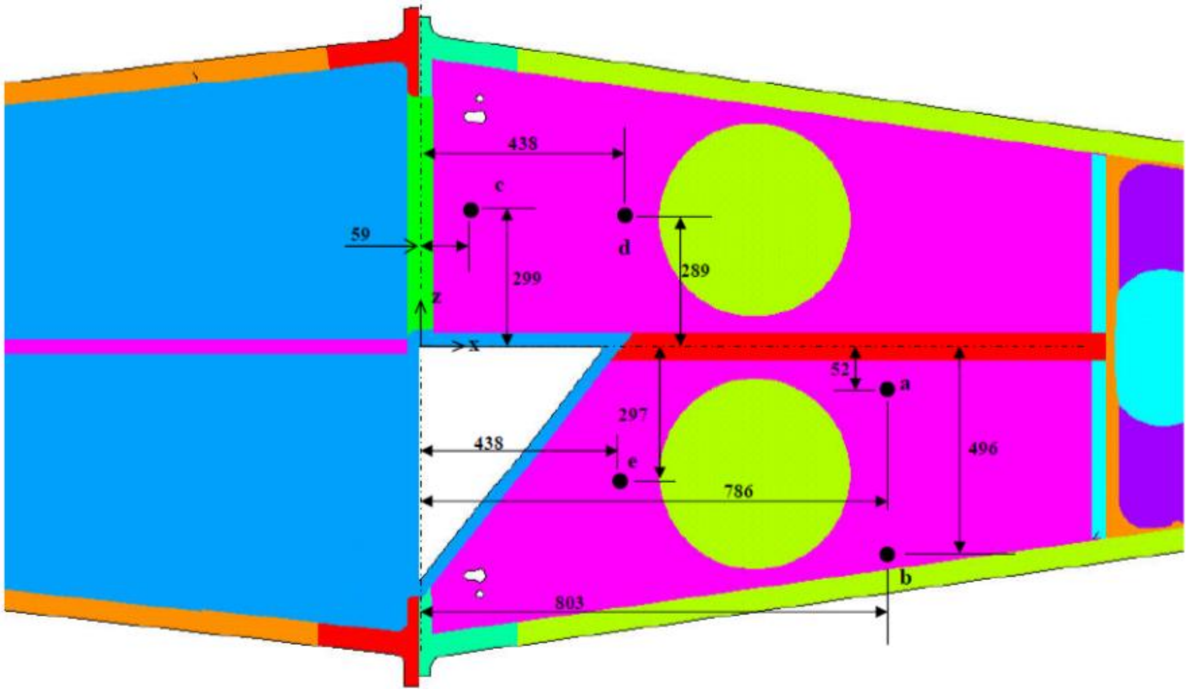

Figure B1 - Strain Gauge Locations a, b, c, d , e on Belly of Aircraft

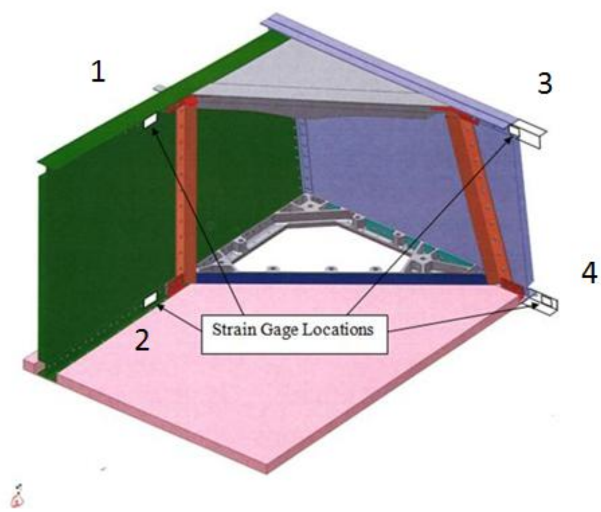

Figure B2 - Strain Gauge Locations 1, 2, 3, 4 Inside Fuel Bay

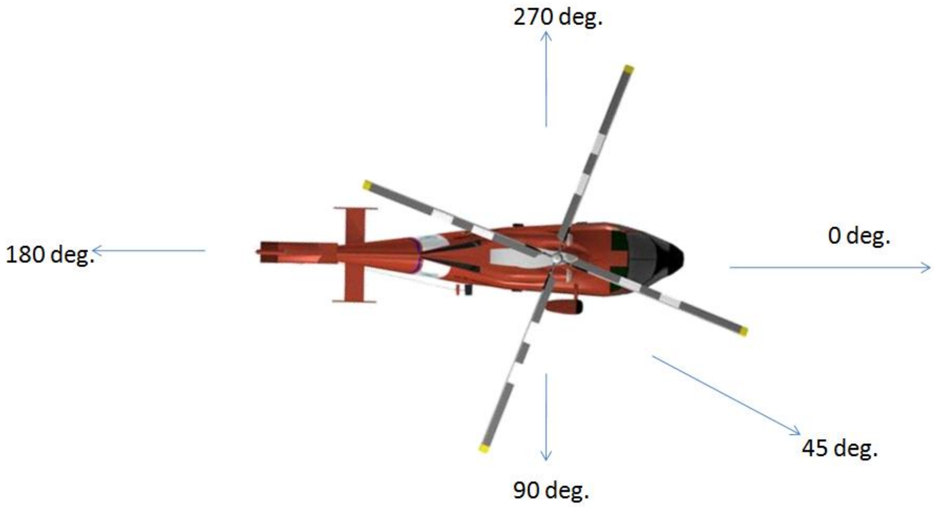

Figure B3 - Directions Aircraft was Statically Pulled

Figure B4 – 45 deg. Load Case

Table B1 - Strain test data

	Load	Location A			Location B			Location C			Location D			Location E			Fuel Cell Area			
	Load	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ex	Ey	Ey
Zero [1]	0.0	0.4	0.6	0.3	0.4	-0.4	0.2	1.1	0.8	0.1	0.6	0.6	0.4	0.0	0.0	1.1	0.1	-2.7	1.3	-1.5
Delta Calc [2]	-0.7	-120.8	27.0	40.9	71.3	64.3	36.1	72.2	94.8	242.9	114.4	52.9	111.2	39.0	159.4	176.9	-167.0	75.5	10.8	N/A
Zero [3]	-0.4	2.4	2.2	2.8	0.5	0.3	0.6	3.8	1.9	0.2	2.7	2.6	1.3	3.1	2.6	0.4	3.8	-0.2	1.6	2.7
0 Deg	Load	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ex	Ey	Ey
	-0.4	2.4	2.2	2.8	0.5	0.3	0.6	3.8	1.9	0.2	2.7	2.6	1.3	3.1	2.6	0.4	3.8	-0.2	1.6	2.7
	500.9	33.0	6.6	-1.6	19.0	2.5	-6.9	4.6	-14.8	-5.9	7.6	-17.5	-8.2	22.2	15.0	-14.1	-27.6	47.9	7.6	-1.9
	999.2	71.0	19.0	-2.3	47.8	11.0	-9.0	6.4	-27.1	-6.6	13.8	-28.1	-13.4	42.1	31.7	-21.9	-66.0	97.0	12.8	-4.1
	1500.0	107.7	26.4	-2.1	74.6	22.0	-10.3	9.5	-45.7	-13.3	20.6	-44.1	-22.7	61.1	43.0	-33.8	-114.6	150.0	24.2	-4.8
	2000.1	143.9	37.6	-3.1	100.0	30.2	-14.3	9.9	-59.8	-16.3	25.6	-56.2	-28.2	78.1	56.6	-41.2	-161.1	201.0	31.6	-8.4
90 Deg	Load	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ex	Ey	Ey
	-0.4	2.4	2.2	2.8	0.5	0.3	0.6	3.8	1.9	0.2	2.7	2.6	1.3	3.1	2.6	0.4	3.8	-0.2	1.6	2.7
	500.2	-6.2	-33.5	-3.7	-0.8	32.1	14.4	-0.9	19.6	12.4	-1.0	-19.1	8.7	1.7	-37.8	-14.0	14.2	10.6	26.8	-5.9
	999.7	-11.6	-61.9	-9.1	5.4	63.7	31.6	-5.9	42.6	28.9	-3.1	-30.7	22.0	-1.2	-73.6	-16.3	18.7	7.9	55.2	-19.7
	1501.1	-18.2	-95.0	-15.3	11.6	100.4	52.6	-12.7	64.7	47.5	-6.1	-44.8	36.5	-4.3	-113.3	-19.8	24.7	6.6	80.5	-39.2
	2000.5	-25.7	-128.1	-21.0	16.8	134.5	71.1	-20.1	85.6	64.1	-9.7	-58.1	49.7	-5.6	-151.5	-26.1	32.0	6.9	108.0	-54.4
180 degree	Load	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ex	Ey	Ey
	-0.4	2.4	2.2	2.8	0.5	0.3	0.6	3.8	1.9	0.2	2.7	2.6	1.3	3.1	2.6	0.4	3.8	-0.2	1.6	2.7
	500.9	-31.4	-12.1	-0.1	-33.2	-5.8	4.0	7.0	11.3	-1.6	-2.5	4.6	2.5	-17.1	-23.9	0.4	31.5	-39.4	-2.0	7.4
	1001.0	-74.4	-25.1	0.4	-65.1	-15.5	6.9	2.3	26.1	2.2	-9.9	18.9	10.7	-39.7	-42.1	9.9	74.3	-89.8	-7.6	10.0
	1501.0	-108.9	-36.9	0.5	-91.4	-22.2	9.5	-3.5	35.4	5.4	-17.5	29.8	17.5	-57.8	-55.0	17.5	111.1	-142.0	-12.6	13.2
	2000.0	-145.6	-44.5	1.4	-118.2	-30.8	10.4	-7.3	49.4	9.0	-25.3	46.2	26.0	-76.5	-65.7	28.3	151.6	-190.0	-18.4	17.4
270 degree	Load	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ex	Ey	Ey
	-0.4	2.4	2.2	2.8	0.5	0.3	0.6	3.8	1.9	0.2	2.7	2.6	1.3	3.1	2.6	0.4	3.8	-0.2	1.6	2.7
	500.9	5.5	21.0	2.9	-14.3	-31.5	-17.3	13.8	-29.0	-25.1	6.2	2.4	-16.4	1.4	27.9	-1.2	-10.6	8.4	-11.8	14.9
	1000.2	10.5	50.6	8.9	-22.6	-65.6	-35.5	19.4	-56.5	-47.8	8.5	13.8	-27.8	0.5	67.2	5.1	-14.4	10.8	-40.4	25.2
	1500.1	16.7	80.1	14.1	-31.3	-97.4	-52.1	24.9	-83.3	-66.7	10.4	24.9	-39.4	-1.7	103.9	13.6	-19.9	12.4	-66.1	40.5
	2001.2	22.9	111.8	20.3	-40.5	-129.7	-69.8	29.0	-111.6	-87.2	11.8	36.9	-52.5	-4.5	141.7	21.3	-26.2	18.6	-95.8	60.2
45 degree	Load	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ey	Exy	Ex	Ex	Ey	Ey
	-0.4	2.4	2.2	2.8	0.5	0.3	0.6	3.8	1.9	0.2	2.7	2.6	1.3	3.1	2.6	0.4	3.8	-0.2	1.6	2.7
	500.2	15.7	-27.4	-3.6	11.5	28.2	9.6	4.8	3.8	2.2	5.8	-30.2	0.9	17.1	-21.0	-21.7	-9.3	42.6	36.6	-5.4
	1000.8	38.8	-38.5	-7.6	37.7	59.1	20.7	2.5	11.5	13.5	8.3	-46.1	6.3	29.8	-34.7	-30.0	-32.0	77.0	55.2	-21.0
	1500.0	63.7	-48.3	-12.1	63.7	88.6	32.3	3.2	23.9	29.5	10.8	-59.6	14.7	40.9	-49.0	-32.6	-55.5	108.0	76.7	-34.3
	2000.9	87.4	-61.9	-16.4	90.2	121.7	45.2	2.7	31.2	39.1	13.6	-77.2	19.5	53.5	-67.4	-39.8	-83.1	142.0	102.0	-47.0

[1] Zero after gage installation (inside hangar)

[2] Difference between weight on 4/27 and weight prior to testing

[3] Zero at 10:50am just before test (outside hangar)

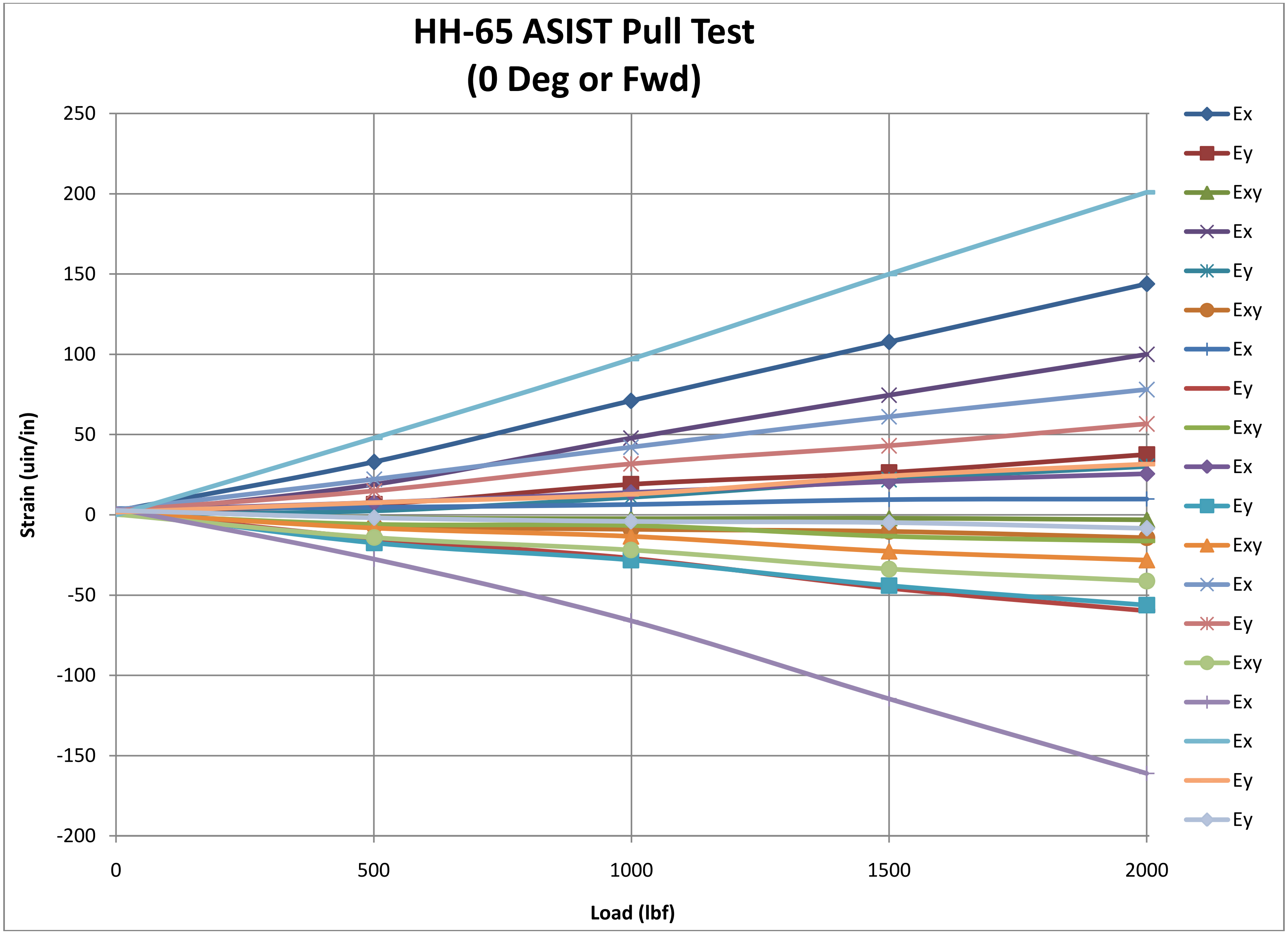

Figure B5 - Load Versus Strain Plot 0 deg. Load Case

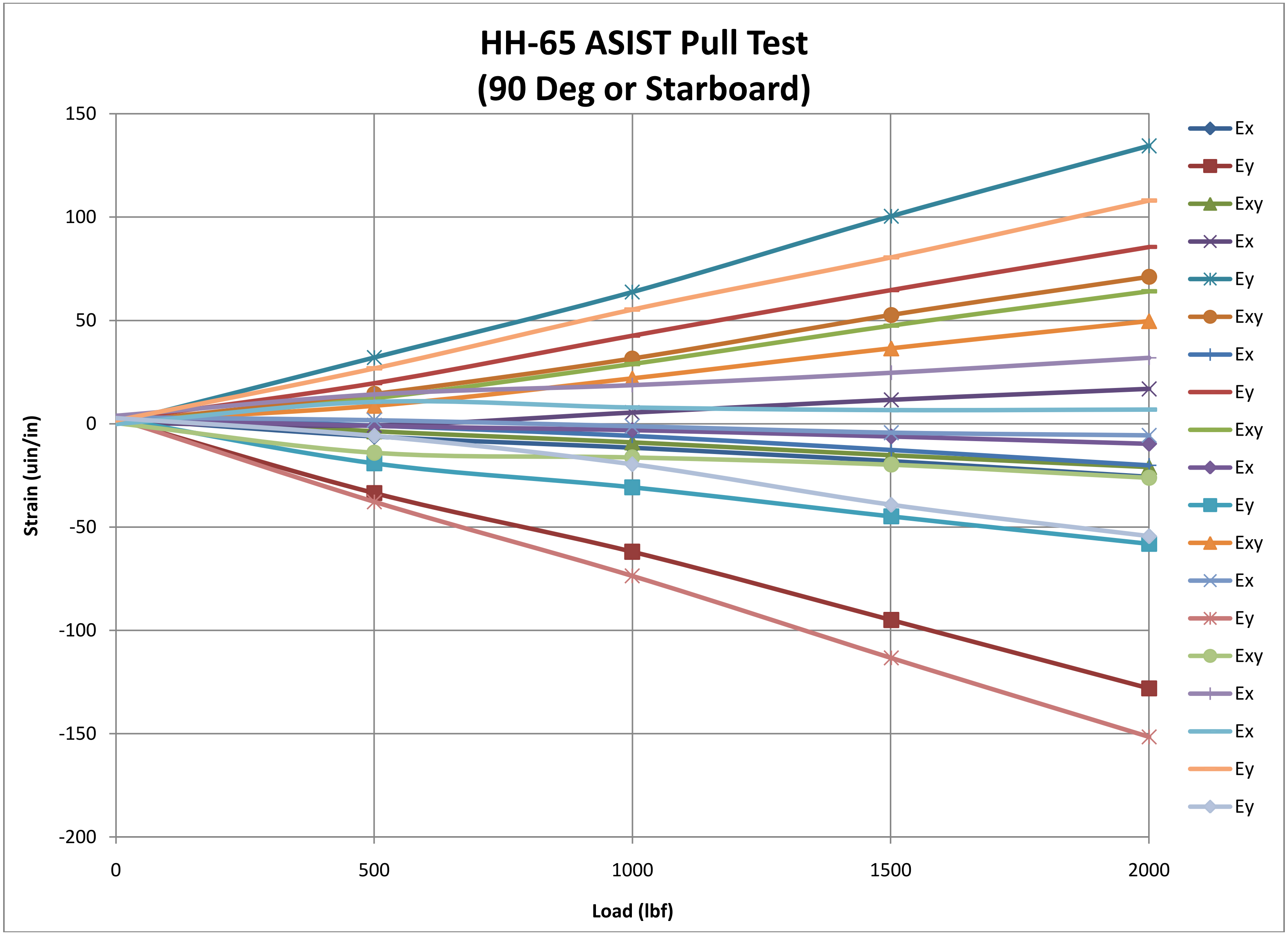

Figure B6 - Load Versus Strain Plot 90 deg. Load Case

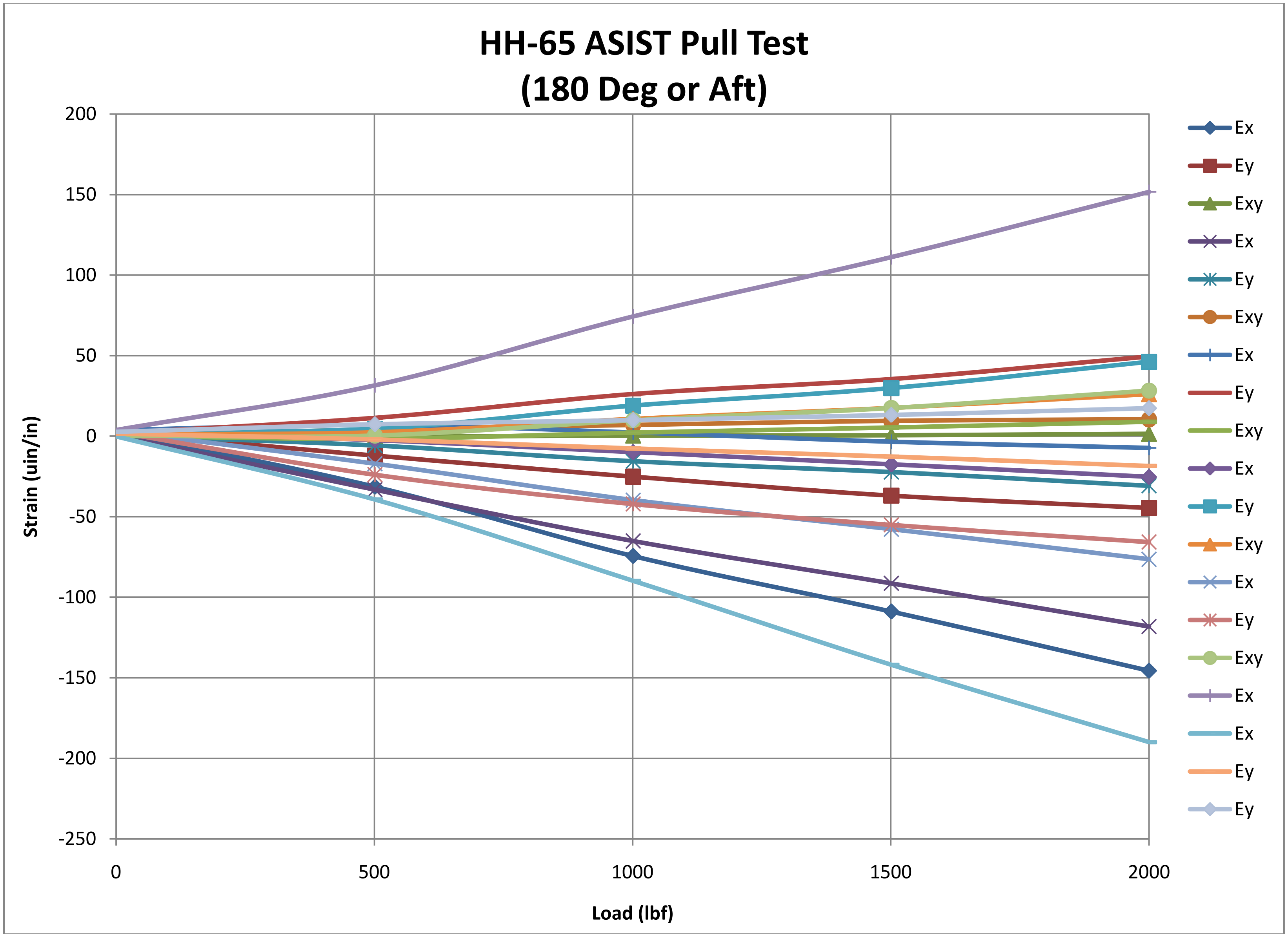

Figure B7 - Load Versus Strain Plot 180 deg. Load Case

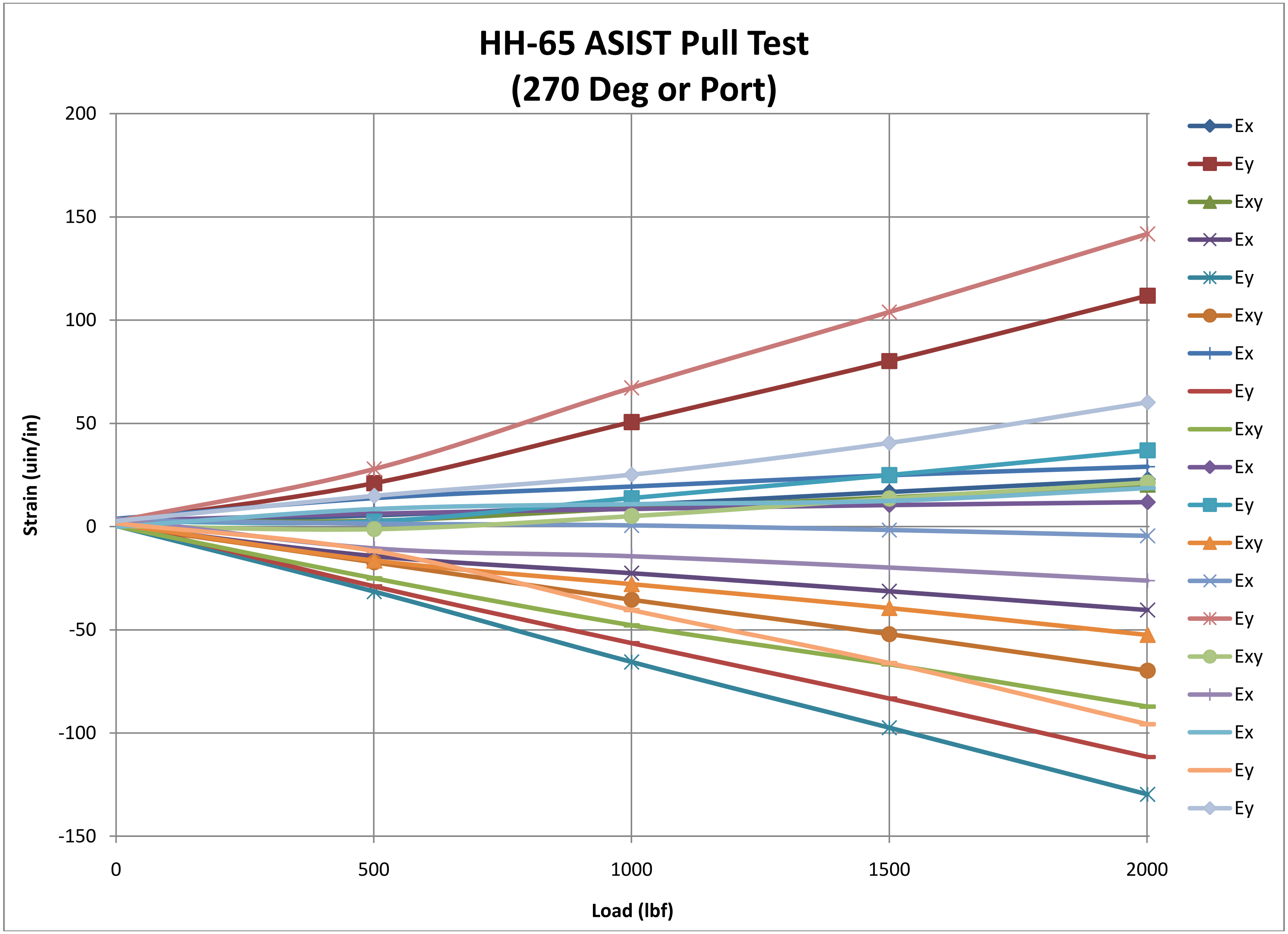

Figure B8 - Load Versus Strain Plot 270 deg. Load Case

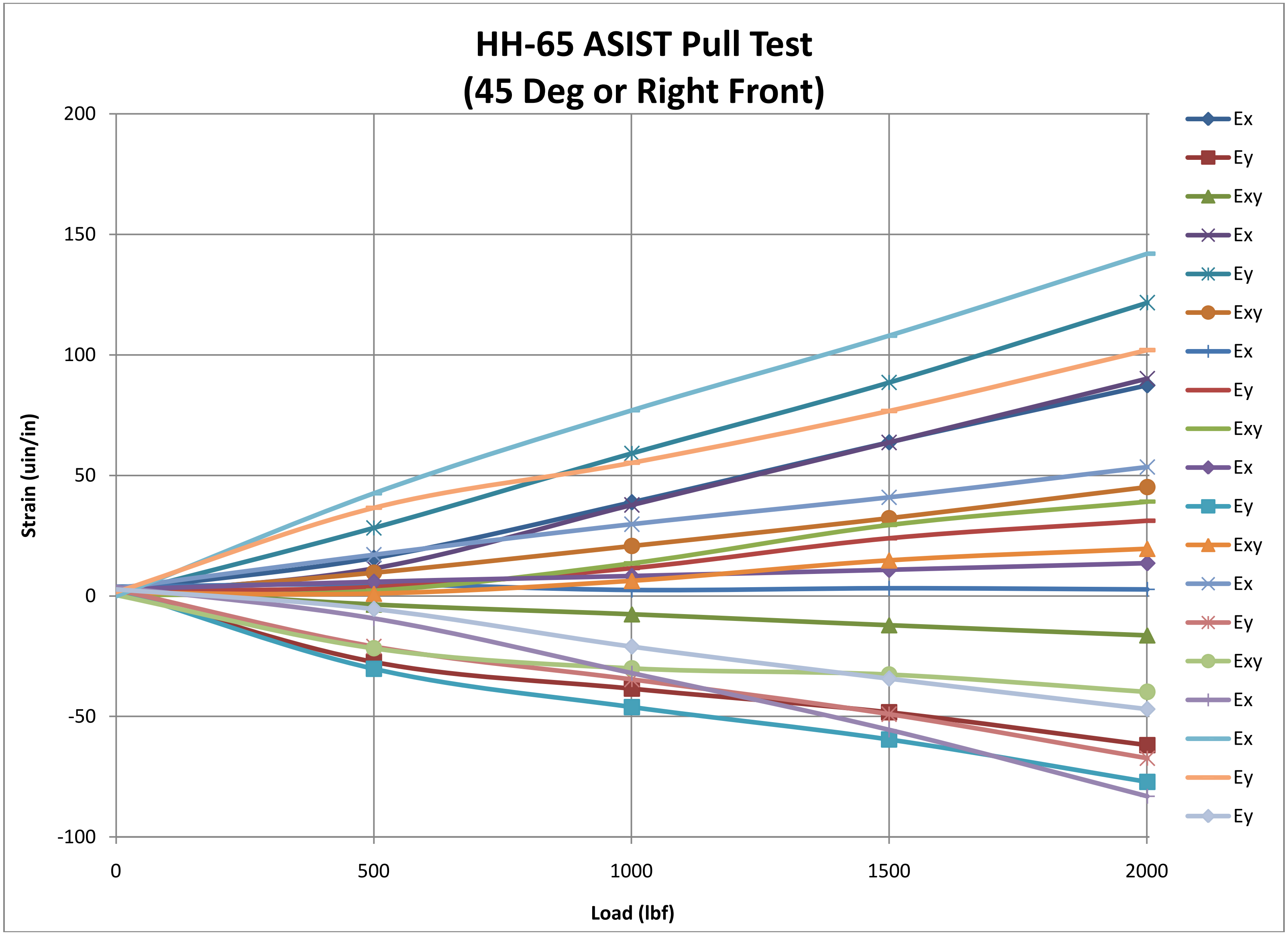

Figure B9 - Load Versus Strain Plot 45 deg. Load Case